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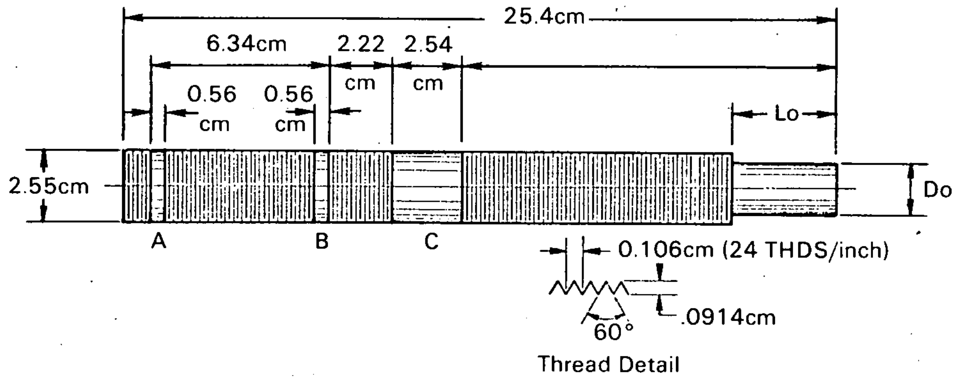
An Ultrasonic Method for Studying Elastic Moduli as a Function of Temperature



Areas A, B, and C denote unthreaded regions of the specimen surface. Areas A and B are the locations of the water jacket O-ring seals; area C is the location of the vacuum seal to the top cover of the furnace.

TYPICAL SPECIMEN CONFIGURATION

The problem:

To determine the elastic moduli of materials used in components of high-temperature nuclear reactors. The elastic constants of such materials are needed so that reactor designers can allow for length changes, stress distribution changes, and other physical effects of mechanical and thermal stresses. Currently two separate measurements are required to obtain these constants.

The solution:

An ultrasonic method for studying the behavior of elastic moduli as a function of temperature up to approximately 1000°C. An ultrasonic, pulse-echo technique is used to determine the velocity of sound waves propagating in a heated region of rod-shaped specimens. A vacuum furnace is used to heat the specimen.

A method for computing the elastic constants (Young's modulus, Poisson's ratio, and shear modulus) from these ultrasonic frequencies, and the specific results for vanadium-20 w/o titanium are given.

How it's done:

The velocities of sound waves in any medium are directly related to the elastic properties of the medium, since both parameters ultimately depend upon the interatomic forces in the medium.

The facility assembled for the study consists of the ultrasonic equipment and a high-temperature vacuum furnace in which the specimens are mounted.

The specimen configuration is shown in the figure. The rod is ~25 cm long and ~2.5 cm in diameter, except for one end, which is ~2.0 cm in diameter.

(continued overleaf)

The end faces and the surface of the shoulder are made as nearly parallel as possible and are flat to within one fringe of sodium light as viewed against an optically flat glass plate. The flat surfaces have a 20-μcm polish on them.

An ultrasonic transducer is coupled to the large-diameter end of the bar which generates sound-waves pulses that travel down the length of the bar. As a pulse reaches the shoulder, where the diameter of the bar changes, part of the sound energy is reflected back to the transducer. The rest of the pulse travels until it reaches the end of the rod, where it also is reflected back to the transducer.

When the two pulses reach the transducer after being reflected, they are detected by the transducer, and the time of arrival of each pulse can be measured. The difference in arrival times is the time required for a sound wave to make a round trip in the small-diameter section of the rod. In actual practice, only the arrival-time difference is measured, not the separate arrival-times.

The longitudinal and shear-wave velocities can be determined by measuring the transit times of waves generated by two separate transducers, each generating its own characteristic type of wave. However, two transducers are not necessary if it is possible to take advantage of the wave guide nature of the rod.

Trailing pulses will be generated in the small diameter section of the rod if longitudinal waves are initially generated at the other end of the rod. Since the delay time between successive trailing pulses is a function of the shear-wave velocity, measurements of both delay time and round-trip transit time in the small end of the rod enable both the longitudinal-wave velocity and the shear-wave velocity to be computed.

From these velocities, the elastic moduli can be calculated. The accuracy of the method is within 0.2% for Young's modulus and the shear modulus, and within 0.03% for Poisson's ratio.

Notes:

1. The determination of elastic constants is useful for a wide range of scientific and industrial organizations.
2. Additional information is contained in "A Facility for Studying Elastic Moduli as a Function of Temperature by an Ultrasonic Method," ANL-7119, February, 1966, Argonne National Laboratory, Argonne, Illinois. This report is available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151; price: \$3.00 (microfiche: \$0.65), Reference: B69-10082.
3. Inquiries concerning this innovation may be directed to:

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Patent status:

Inquiries about obtaining rights for commercial use of this innovation may be made to:

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